IN THE UNITED STATES DISTRICT COURT

FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex rel.)
W.A. DREW EDMONDSON, in his)
capacity as ATTORNEY GENERAL)
OF THE STATE OF OKLAHOMA,)
et al.)
)
Plaintiffs,)
vs.)CASE NO. 05-329-GKF-PJC
)
TYSON FOODS, INC., et al.,)
)
)
Defendants.)

TRANSCRIPT OF NONJURY TRIAL PROCEEDINGS
JANUARY 7, 2010
BEFORE GREGORY K. FRIZZELL, U.S. DISTRICT JUDGE
VOLUME 88, A.M. SESSION

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THE COURT: Mr. Smithee.

MS. TUCKER: Yes, sir. We'd like to continue with the videotaped deposition of Derek Smithee. For your reference, we'll begin with clip No. 27.

THE COURT: All right.

(Video deposition of Mr. Derek Smithee was continued.)

THE COURT: Exhibits?

MS. TUCKER: No.

THE COURT: The defendants may call their next witness.

MR. GEORGE: Your Honor, the defendants call Dr. Victor Bierman.

(Witness sworn.)

THE COURT: State your full name for the record, please, sir.

THE WITNESS: My full name is Victor Joseph Bierman, Jr.

THE COURT: That's B-I-E-R-M-A-N?

THE WITNESS: Yes, sir, it is.

THE COURT: You may proceed.

DR. VICTOR BIERMAN, JR.,

having been first duly sworn, was called as a witness and testified as follows:

DIRECT EXAMINATION

BY MR. GEORGE:

Q. Good morning, Dr. Bierman.

A. Good morning.

Q. Dr. Bierman, can you begin by providing His Honor with a brief summary of your educational experiences and degrees.

A. Yes. I have an A.B. degree from Villanova University in 1966 with a major in science. I have a master's degree in physics from the University of Notre Dame in 1971, and a Ph.D. in environmental engineering from Notre Dame in 1974.

Q. Doctor, is it true that there's a bit of a football rivalry between Notre Dame and the University of Michigan?

A. That would call for speculation on my part. But if His Honor is interested, I can provide the name of a football coach who I think is still probably available.

THE COURT: I think we may have your future athletic director in Tulsa. Go ahead.

Q. (By Mr. George) Just so we're clear, Doctor, you don't personally harbor any animosity against the University of Michigan, do you?
A. Is that a trick question?
MR. GEORGE: I'll withdraw the question, Your Honor.
THE COURT: And you expect me to believe this man?
THE WITNESS: I think what I should say is: Talk to my lawyer.
MR. GEORGE: Full transparency, Your Honor.
Q. (By Mr. George) Doctor, you mention that you have a Ph.D. What's the topic of your Ph.D. dissertation?
A. I developed a novel mathematical model for algal growth in eutrophic lakes.
Q. Was that developed or used in any particular waterbodies or geographic areas?
A. Well, I built the model using data from lakes in Indiana and Wisconsin.
Q. Could you please summarize your professional work history following obtaining your Ph.D. in 1974.
A. My first job was as a systems ecologist in 1974 for Cranbrook Institute of Science. At the time, Cranbrook was a U.S. EPA contractor. I then spent

13 years as an environmental scientist with the U.S. Environmental Protection Agency, eight years at the Great Lakes laboratory in Grosse Ile, Michigan, and five years at EPA's marine laboratory in Narragansett.

Q. Stop there for a moment. With respect to your work in the '70s and '80s with the Environmental Protection Agency, did your duties involve developing and applying water quality models?

A. Yes. My principal duties were development and application of water quality models for nutrients and toxic chemicals.

Q. After you left the agency in 1986, what did you do next?

A. I became an associate professor at the University of Notre Dame in the department of civil engineering. Then in 1990, I left Notre Dame, and I became employed at Limno-Tech. I retained an appointment at the university as an adjunct professor for a few years to continue conducting research. And then I transitioned full time to consulting.

Q. Let's talk about your tenure as a professor at the University of Notre Dame. Did you have teaching responsibilities at the university?

A. Yes, I did.
Q. What types of courses did you teach?
A. I taught a numerical methods course for undergraduates. Then I taught a senior undergraduate and a graduate course in water quality modeling.
Q. Other than your time as a professor at the University of Notre Dame, were you affiliated in a professional capacity with any other university?
A. When I was at the EPA lab in Narragansett, I also served as an adjunct professor there and did some collaborative research with modeling of metals in Narragansett Bay. I collaborated with one of the faculty on a metals water quality model for Narragansett Bay.
Q. Doctor, did you have teaching responsibilities at the University of Rhode Island?
A. No, I had no teaching responsibilities there.
Q. Now, let's move to Limno-Tech. When did you join the consulting firm of Limno-Tech?
A. In 1990.
Q. What type of work have you focused on during your employment at Limno-Tech?
A. The work I do, two principal categories. I develop -- I conduct applied research on water

quality and watershed models, and I do this primarily for government agencies, federal, state, regional government agencies. And I also do a lot of scientific peer review work for government agencies, sometimes regulatory agencies and, in some cases, regulated parties.

Q. Doctor, can you provide the court with some information about the consulting firm Limno-Tech and how you fit into that firm?

A. Yes. It's a 75 staff. We are an environmental science and engineering consulting company. We -- primarily we conduct quantitative assessments and develop models for watersheds and water quality modeling. The home office is in Michigan; Ann Harbor, Michigan, actually. We have a regional office in Washington, D.C. with about 10 people. Myself and two other staff work in different locations. I work out of my home in Greensboro, North Carolina. And we have two other staff who work in the same fashion.

Q. Doctor, you mentioned that Limno-Tech has a rather large staff. Did you work with staff members in connection with your responsibilities for this case?

A. Yes, I did. I had four staff people who

constituted my principal core staff, and there were perhaps three or our four other staff who came in and out of the project on a task-specific basis.

Q. Let's talk about your four primary staff members that you work with. Are these individuals that you have had some experience working with on other projects?

A. Yes. The four core staff have a combined total of 85 years of professional experience, and I have a combined total of 62 years' professional experience working with these core staff.

Q. And, Doctor, were you the project leader for this particular case and Limno-Tech's involvement in this case?

A. Yes, I was.

Q. As project leader, did you review all work product of the staff members who assisted you?

A. Yes, I did.

Q. And you understand you're here today to offer some expert opinions relative to this case? You do know that?

A. Yes, I do.

Q. Are the opinions that you are going to express here today your own?

A. Yes, they are.

Q. Doctor, you've issued an expert report in this case; is that correct?
A. Yes.
Q. Did anyone other than yourself contribute to the writing of that report?
A. No, I wrote the entire report.
Q. Doctor, this particular lawsuit involves Lake Tenkiller and the Illinois River. What other notable waterbodies have you focused on in your professional work?
A. Over the years, I've worked on Chesapeake Bay, the Gulf of Mexico, the Great Lakes, Lake Okeechobee, the Everglades, the Hudson and Columbia Rivers, Potomac and Delaware River estuaries, among others.
Q. You mentioned the Chesapeake Bay. What work have you done in the Chesapeake Bay, and for what clients?
A. The first -- I'll put it into two broad categories. The first project was actually a multiyear project, involved conducting a scientific assessment of the Chesapeake Bay water quality model and the use of that model to develop cap loadings for nutrients and sediments to Chesapeake Bay and these -- which were embodied in the Chesapeake 2000

agreement.
Q. Who was your client for that particular project?
A. That was the Metropolitan Washington, D.C. Council of Governments.
Q. Did you have another project related to Chesapeake Bay?
A. Yes. I had actually a series of three research projects that played out over about six or seven years. They were funded by the U.S. Army Corps of Engineers, and it involved advancing the state of the science of the Potomac portion of the Chesapeake Bay water quality model. We enhanced the phosphorus kinetics, we put pH-alkalinity into it, and I developed a novel algal speciation submodel for it.
Q. One of the other waterbodies you mentioned is the Gulf of Mexico. What projects were you involved in related to the Gulf of Mexico?
A. Again, there were long-term projects. I categorize it by saying that the first of them was development of a water quality model for nutrients, chlorophyll and dissolved oxygen. And this was in the Gulf of Mexico, and this was directed at the hypoxia problem, the so-called dead zone in the Gulf of Mexico.

Q. Who was your client for that project?
A. That was the National Oceanic and Atmospheric Administration.
Q. Did you have a subsequent project related to the Gulf of Mexico?
A. Yes. The White House Committee on Environment and Natural Resources initiated a Gulf of Mexico hypoxia assessment that involved six work groups. And I co-chaired one of those work groups. And that involved using the results of the mathematical model that I had developed previously to help develop the coastal goal, to develop the nitrogen load reduction goal for the Gulf of Mexico to reduce hypoxia. And that goal was embodied in the 2001 Federal Action Plan.
Q. You mentioned nitrogen. Is nitrogen the primary nutrient of concern for the Gulf of Mexico?
A. Nitrogen is considered to be the principal nutrient that drives the dissolved oxygen problem.
Q. Doctor, do you have any experience specifically with modeling or evaluating the modeling of nutrients through a watershed system?
A. Yes, I do.
Q. Could you explain that -- can you provide some examples of that experience, please.

A. I can provide some examples. One example is that I developed what we called an Everglades Water Quality Model. That was a model that represented about half of the area in south Florida, and it represented the hydrology and it represented the transport of phosphorus in the overland areas and the canal system of south Florida.
Q. Can you provide any other examples?
A. I conducted a review of a coupled watershed receiving water model for the Caloosahatchee River estuary. I assessed movement of nutrients through the watershed and into the Caloosahatchee River and through the Caloosahatchee River estuary. This was a model that was used by the Florida Department of Environmental Protection to support a TMDL for the Caloosahatchee.
Q. Have you ever reviewed any watershed models that were used in the state of Minnesota?
A. Yes. EPA retained me to conduct an independent peer review of a linked watershed water quality model involving HSPF and AQUATOX. And the agency put forth this model as a demonstration study for the use of models to develop nutrient criteria. So I conducted a peer review of that model for the agency.

Q. Doctor, do you also have experience in tributary loading estimation models?
A. Yes, I do.
Q. Could you --
A. Would you like me to --
Q. -- summarize that experience.
A. I conducted two applied research projects with funding from the U.S. Geological Survey. And the purpose of these projects was to develop and test with real data USGS tributary loading estimation methods. I produced a couple of USGS reports. We have two papers in the peer review literature.
In 2001, I was invited to give a training workshop in tributary loading estimation methods at a national meeting of the Water Environment Federation, and the topic of the meeting dealt with TMDL science issues.
Q. Doctor, has any of your work related to tributary loading estimation been cited by EPA in its guidance documents?
A. Yes. There's a -- EPA supported the development of a technical guidance document for tributary load estimation, and my published work is cited in the annotated bibliography of that document.

Q. You're here today testifying as an expert witness in litigation. Has that sort of work been a significant part of your professional career over the last 20 years?
A. Not a significant part. I've been involved in about 60 different projects with Limno-Tech, and probably 15 percent of them are litigation projects.
Q. Prior to your work in this case, had you ever been retained by any of the poultry companies that are named as defendants in this lawsuit?
A. No, I've not.
Q. Apart from your work for the defendants in this case, have you had any other contact with the counsel for the State of Oklahoma?
A. Actually, yes. In August of 2007, I received an e-mail from Mr. David Page pertaining to litigation in a case in Oklahoma. And in response to his request, I telephoned him, and he then inquired about my interest and availability to be a testifying expert in this present case.
Q. I assume you declined?
A. I told Mr. Page that I was conflicted out.
Q. Doctor, have you been retained to evaluate water quality or fate and transport issues by any federal governmental agencies?

A. Yes, I have.
Q. Could you identify some of those federal agencies and provide some examples of your work for them.
A. I'll give you examples involving three agencies, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and U.S. Department of Justice.
For EPA, I developed a transport and fate model for PCBs in the upper Hudson River, and this was part of the remedial investigation feasibility study. The results of my transport and fate modeling were characterized by EPA as the backbone of their decision, their record of decision to dredge contaminated sediments in the Hudson.
Another EPA project was I developed a transport and fate model for PCBs for the Potomac River estuary, and those results were used to develop a PCB TMDL under terms of a court-ordered consent decree.
Another project was -- I think I mentioned this, the peer review of the coupled HSPF-AQUATOX model.
Q. Doctor, other than the United States Environmental Protection Agency, have you worked for

any other federal agencies?

A. The Corps of Engineers, there are two projects I could cite in response to the question. One is a -- I'm currently sitting on an independent external peer review panel for -- to review the water quality aspects of a proposed Corps of Engineers flood control project in the St. Johns Bayou/New Madrid Floodway in the state of Missouri.

Another project for the Corps of Engineers, they applied a rather sophisticated water quality model to the lower St. Johns River in Florida. They had some problems with the calibration, and they involved nutrients and algal speciation and nitrogen fixation, and they called me in and retained me to review that work and provide expert assistance to them.

Q. Doctor, have you done any work with the U.S. Department of Justice?

A. Two projects with the Department of Justice. As a follow-on to the PCB transport and fate model I did in the upper Hudson, the Department of Justice initiated an NRDA case, natural resources damages assessment case, in the upper Hudson River pertaining to the PCB contamination, and I was retained as a consulting expert to DOJ for that

case.
Q. Doctor, you mentioned a time or two that you have been periodically retained to peer review models.
A. Yes.
Q. When you are retained in that capacity, to peer review a model, is it always a model or an application that you have seen previously?
A. Well, usually it's not an application I've seen previously. That's why you're normally asked to review these things. Every site-specific application is unique. No two are the same. They all have unique aspects.
I may or may not be familiar with the model. I frequently am. But if I'm not familiar with the model, I'm certainly familiar with the science underlying the model.
Q. When you encounter a model that you have not had particular experience with that tool, what steps do you take to familiarize yourself with the model?
A. Well, first step would be to review the user manual and any papers or reports that pertain directly to the model, that is the tool, and the science underlying that tool.
The second step would be to review any

papers and reports pertaining to the particular site-specific application of the model in question.

The next later layer would be to actually review the model files themselves, the data inputs, the model files, the model outputs. And, again, depending on the nature of the review, depending on the rigor, the last level would be actually running the model itself and testing it and conducting diagnostic analyses.

Q. Did you follow a similar process in this case with regard to Dr. Engel's models?

A. Yes, I did. I followed exactly that process.

Q. Let's talk about your publication history. Have you published the results of your professional work over the years in any scientific journals?

A. Yes. I have a total of over a hundred publications, and they would be journal articles, book chapters, technical reports. About half of those are peer reviewed, were peer reviewed, most of them in journals. Some of them have appeared as peer-reviewed book chapters.

Q. Doctor, have you served on any editorial boards of peer-reviewed journals?

A. Yes. I've served on two editorial boards: *Journal of Great Lakes Research* and *Aquatic*

Ecosystem Health and Management.
Q. In addition to serving on those boards, are you periodically asked to review technical papers as part of the peer review process for other journals?
A. Yes. I routinely review manuscripts for journals, *Environment Science and Technology*, *Lake and Reservoir Management*, *Estuaries and Coasts*, to name three of them.
Q. Doctor, are you a member of any respected professional associations that you believe are relevant to your work in this case?
A. Yes, I am.
Q. Could you identify a few of those, please.
A. The American Chemical Society. They produce, among other things, the *Journal of Environmental Science and Technology. It's* probably the most widely read journal in the field.
North American Lake Management Society, American Society of Limnology and Oceanography. Water Environment Federation.
Q. Thank you. Are you, Doctor, currently serving on any technical or scientific advisory committees for EPA?
A. Yes, I am.
Q. What is that committee?

A. That is the Environmental Processes and Effects Committee. It's a standing committee of the U.S. EPA Science Advisory Board.

Q. What is the charge or the task for that committee?

A. Our task is to conduct an independent peer review of a draft technical guidance document that EPA prepared for the development of nutrient criteria.

Q. And do I understand that there are some standing members to that committee?

A. Yes. The committee has 14 standing members. And for this particular task, they decided to bring on six additional consultants with specialized expertise in this particular peer-reviewed topic.

Q. Could you briefly describe the process that you underwent to become one of the six consultants for this EPA committee?

A. EPA put out a public notice in the Federal Register soliciting nominations for this assignment. There were 27, short list of nominees at the next step, and these 27 nominees along with short bibliographies were put out, were publicly noticed on EPA's website. There was a 60-day public comment period, and at the end of that process, EPA

selected six of the 27.
Q. Is Dr. Andrew Sharpley also one of the consultants hired by the EPA Science Advisory Board to work on this peer review process?
A. Yes, he's one of the six.
Q. Doctor, let's turn to the scope of your work in this particular lawsuit. What issues or subjects were you asked by the defendants to evaluate in this case?
A. I was asked to evaluate and review and to make a determination about the validity and the reliability of the watershed and water quality models put forth by Dr. Engel and Dr. Wells.
Q. What information or data did you review as part of your analysis in this case?
A. Well, I followed the stepwise process that I discussed previously. The first step was -- well, I guess for the particular case, where I started was the expert reports, the paper reports. And then there was a considerable amount of produced material, electronic files. We reviewed those.
I reviewed many papers and reports pertaining to data and water quality on the Illinois River Watershed. And I also reviewed the current and relevant EPA guidance. EPA has a number of

guidance manuals. One of them pertains specifically to the development and evaluation and the application of environmental models.

Q. Doctor, you mentioned that one of the first things you reviewed was expert reports. You're referring to experts from the State of Oklahoma?

A. Yes. The reports -- most of my attention was focused on Drs. Engel and Wells, but I also reviewed the portions of the reports by Drs. Stevenson and Cooke and Welch that used modeling results from either Dr. Engel or Dr. Wells.

Q. Obviously today, Doctor, our discussion is going to focus on the models. Can you explain, before we get too far into this, what Dr. Engel's model consisted of, just generally.

A. Right. In general terms, Dr. Engel's model was actually two models. The GLEAMS model represented the flow and the nonpoint source phosphorus loads that -- to the edge of the field. The second model, his so-called routing model, seeks to establish a connection between those edge-of-field loads plus wastewater treatment plant loads, which were determined separately and added in, and the loadings to Lake Tenkiller at the three outlet stations at the base of the watershed.

Q. You mentioned Dr. Engel's routing model. Is his routing model really a model, as you would use that term?
A. I wouldn't call it a model. I would call it an empirical equation.
Q. When Dr. Engel provided his expert report in May of 2008, what did you receive in terms of the models?
A. We received a very large number of files: Input files, model files and output files. We received many different versions of each file: Inputs, coding and outputs.
Q. Doctor, once you received those computer files, did you and your staff have to assemble those files into a working version of the models as part of your work?
A. Yes. Consistent with the stepwise process I discussed earlier, we reviewed the model files and then we took the next step, and attempted to test the model by actually running it.
Q. Doctor, could you briefly describe the process and some of the difficulties that were encountered in trying to assemble those electronic files into a working version of the model.
MR. PAGE: Objection, leading, Your Honor.

MR. GEORGE: I asked him to describe, Your Honor.

THE COURT: Overruled.

THE WITNESS: We could run the model without any trouble. That was not the problem. The problem was we could not run the model in such a way that we could reproduce the results in Dr. Engel's report. And some of the difficulties were there were very many different versions of input files, there were many different versions of model code, and there were many different versions of output files. And Dr. Engel's report did not document in sufficient detail which pieces were which, how to put them together, in what order to put them together.

So as I said, we could run the model, but we had no way of knowing how to run it, how to assemble the pieces in such a way as to reproduce the results in his report.

Q. Did you participate in some back and forth with the lawyers and Dr. Engel to try to get some clarity and some gaps filled?

A. Yes, we did.

Q. Could you briefly describe that process.

A. Well, I think it started with e-mail

exchanges. I prepared some e-mails with questions pertaining to asking for more specific descriptions of files, more specific descriptions of what version was used and how it was used, how they were used.

I should say that as we got deeper into the process, it became apparent that it was not just an assembly problem; we were actually missing important files which, in fact, we never would have been able to run the model in such a way as to produce the results in the expert report, because the original production simply did not contain the files that allowed us to do that.

Q. In the midst of that process, did you receive an errata report from Dr. Engel?

A. Yes, we received the report in September of 2008.

Q. Okay. And can you provide the court with your understanding of what necessitated that errata.

A. My understanding --

MR. PAGE: Objection, Your Honor, lack of foundation.

MR. GEORGE: I'll ask the question to establish foundation.

THE COURT: Very well.

Q. (By Mr. George) Doctor, did you review the

errata?
A. Yes, I did.
Q. Does Dr. Engel provide a description of why the errata was necessary in that report?
A. Yes, he did.
Q. Can you provide the court, by way of background, with your understanding the need for the errata in September 2008.
A. Yes. I need to back up and set some foundation. Dr. Engel applied his GLEAMS model to the Illinois River Watershed -- he broke the watershed up into 50 different spatial units, and those are called hydrological response units. I'll call them HRUs.
And my understanding of the problem was that in attempting to answer our questions and in pulling together the missing files for us, Dr. Engel discovered what was actually a serious flaw with the GLEAMS model results that had been given to us with his original expert report.
The simplest way to describe it is that he discovered that the results in his original expert report only represented 27 of the 50 HRUs. He had left out 23 of them.
Q. Now, Doctor, with respect to Dr. Engel's errata

that he produced in September of 2008, did he purport to have corrected that mistake?

A. He stated that he corrected the mistake, and included all 50 HRUs, that's right.

Q. In the errata, did Dr. Engel reach results that were substantially different from his original report?

MR. PAGE: Objection, leading, Your Honor.

THE COURT: Sustained. Rephrase.

Q. (By Mr. George) How would you describe the results that Dr. Engel reached as between his first errata -- his original report and his first errata?

A. Answer the question in two parts. All the numbers were different. And we got a whole new set of model files. However, Dr. Engel characterized those differences as not significant, and he stated that none of his opinions changed from the original report.

Q. Dr. Bierman, were you concerned that Dr. Engel's model could support similar results with half the watershed missing?

MR. PAGE: Objection, Your Honor, leading.

MR. GEORGE: Can be answered yes or no.

THE COURT: Sustained.

Q. (By Mr. George) Dr. Bierman, did that

explanation provide you any -- cause you any concern?

MR. PAGE: Same objection, Your Honor.

THE COURT: Overruled.

Q. (By Mr. George) Please answer.

A. Well, it caused concern because basically Dr. Engel's model gave the same answers for the entire Illinois River Watershed as it gave when half the watershed was left out. I mean, common sense told me that this is a red flag. There's a serious flaw somewhere in that model.

Q. Now, Doctor, we've talked about the first errata. Was that the final answer, if you will, of Dr. Engel with respect to his modeling work?

A. No. No, there was another errata or -- this was in October. We were again provided with different numbers and new model files.

Q. Doctor, did you run a series of simulations using Dr. Engel's routing model?

A. Yes, I did.

Q. What was the purpose of those simulations?

A. The routing model relates the nonpoint source phosphorus loads computed by Dr. Engel's GLEAMS model plus wastewater treatment plant loads to his observed total phosphorus loads at the three outlet

stations at the bottom of the watershed.

And the purpose for me conducting -- I wanted to check the routing model. I wanted to confirm or determine whether or not it could actually pin down the loadings from the watershed and relate them to the loadings at the outlet stations.

Q. What approach did you use to confirm or test the routing model?

A. Well, I did some sensitivity analyses with the model, and that involved putting in different input loadings to determine how the model would respond.

Q. And without going into a lot of detail, because we'll come back to these in a moment, can you list for the court the specific tests or sensitivity analysis that you performed on the routing model?

A. Yes. I did four tests. The first test consisted of not changing the magnitudes of the input loads that Dr. Engel put into the routing model, but just reversing the time order. This model was applied to the period from 1998 through 2006, so I just took -- I took the load on the last day, made it first, and reversed everything and ran the time series backwards.

The second thing I did was I then modified

the changed -- I changed the loadings from the loadings that Dr. Engel put into the model, and I put my own loadings into the model. I increased the wastewater treatment plant loads by a very substantial amount. I then increased the nonpoint source loading component. And then finally, I decided to just use made-up numbers, put them in and see what would happen, and that was -- the numbers I chose to use were the S&P 500 Stock Index values for the period 1998 through 2006.

Q. Let's talk about each of these in order. Let's start with where you ran the model load -- with the loads backwards. What was the purpose of that analysis?

A. Dr. Engel explained that the one thing the routing model does is it redistributes -- it distributes loads and time to make sure that the -- not only that the right -- that the loads are the right magnitude make it to the bottom of the watershed, but they there at the right time.

So I thought this would be a test of the timing of the model. Basically it was a test to see whether the model could tell the difference between days on which it's not raining, on days which it is raining, because on days on which it's raining, you

can get nonpoint source runoff.
Q. Doctor, did you have an expectation as to whether the results would change, having reversed the loads?
A. Well, certainly, yes, I expected the results would change.
Q. Doctor, did you prepare for your report a chart showing the results of this first test or analysis?
A. Yes, I did.
Q. Do you have a binder with the exhibits?
MR. GEORGE: David, you have the exhibits, don't you?
MR. PAGE: Yes.
MR. GEORGE: Your Honor, you have a binder as well?
THE COURT: Yes.
Q. (By Mr. George) Could you turn to tab 2 in the binder and find Defendants' Joint Exhibit 2414.
A. Yes, I'm there.
Q. Can you identify for the record Defendants' Joint Exhibit 2414.
A. Yes. This is Figure 19 from my expert report.
Q. And did you prepare this exhibit?
A. Yes, I did.
Q. And can you identify the source of the

information of data that's shown on this exhibit.
A. Yes. Again, some more foundation. Dr. Engel applied his linked GLEAMS routing model system separately to each of three subwatersheds in the Illinois River Watershed. He -- these three panels here show results for each of these three subwatersheds. The top panel represents the results for the Illinois River subshed, the middle is Barren Fork, the bottom was Caney Creek.
In each of these plots, the X axis, the horizontal axis here, represents Dr. Engel's observed phosphorus loads at the bottom of the watershed at the USGS station at the bottoms of each of these three respective watersheds.
The vertical axis represents the predicted loads from the routing model.
MR. GEORGE: Your Honor, at this time, I move for the introduction of Defendants' Joint Exhibit 2414.
THE COURT: Any objection?
MR. PAGE: No objection, Your Honor.
THE COURT: 2414 is admitted.
Q. (By Mr. George) Doctor, with reference to this exhibit, could you please explain what that figure shows about the results of the first test.

A. Yes. The test I conducted was, one, I changed the order of the loads; and then, two, I attempted to calibrate -- recalibrate the model exactly the way Dr. Engel claims to have calibrated it and validated it in his expert report. And basically I did a regression analysis of predicted versus observed phosphorus loads, exactly as Dr. Engel had done it. And these plots here depict the results.

The lines in each plot represent the fitted regression line. The metric that I used to determine how -- the goodness of fit is the so-called R^2 -- it's the same the metric Dr. Engel used for his calibration validation. And the type is a bit small, but the R^2 is reported for each of fits for each of these three subwatersheds.

Q. How does your R^2 compare to the R^2 reported by Dr. Engel?

A. As good or better.

Q. What conclusion, if any, do you draw from this analysis, Doctor.

A. Simply put, Dr. Engel's routing model can't tell the difference between dry days and rainy days in the Illinois River Watershed.

Q. Let's talk about the test that you ran where you -- I think you said you increased the wastewater

treatment plant loads and the nonpoint source inputs, right?
A. Yes, I did.
Q. What was the purpose of that analysis?
A. Well, the purpose was to check the model to determine -- the question I was asked is this: Can that routing model -- can it actually pin down the loadings from the watershed and relate -- and make them fit, tightly constrain them to the observed loads at the bottom of the watershed.
And to test whether -- to test how tight the connection is between the loads Dr. Engel put in and his observed loads at the bottom of the watershed, I changed the loads that he put in and determined whether or not the model could still fit the loads at the bottom of the watershed.
Q. For your expert report, Doctor, did you prepare a chart illustrating the magnitude of the increases that you applied to these input values?
A. Yes, I did.
Q. Could you turn to tab 3 in your binder and find Defendants' Joint Exhibit 2415.
A. Yes, I'm there.
Q. And for the record, could you identify Defendants' Joint Exhibit 2415.

A. Yes. That's Figure 20 from my expert report.
Q. And what's the source of the information or data shown on Defendants' Joint Exhibit 2415?
A. The top panel contains the inputs that I used for wastewater treatment plants for the second of my four tests. The bottom panel contains the nonpoint source phosphorus loadings I used for the third of my four tests.
Q. Doctor, did you prepare Defendants' Joint Exhibit 2415?
A. Yes, I did.
MR. GEORGE: Your Honor, at this time, we'd offer into evidence Defendants' Exhibit 2415.
MR. PAGE: No objection.
THE COURT: 2415 is admitted.
Q. (By Mr. George) Doctor, what does this figure show about the magnitude of the increases in this particular test that you applied to the wastewater treatment plant loads and the nonpoint source loads?
A. Again, I'll note again that the model was run for 19- -- for each year from 1998 to 2006. So we see bars for each year. Let's look at the green bars. The green bars are there just for reference. They represent Dr. Engel's observed phosphorus loads

to Lake Tenkiller.

The red bar -- let's go to the top panel. For the top panel, the red bar represents the magnitudes of the wastewater treatment plant loads that Dr. Engel put into his routing model. And the blue bars represent the substantially increased wastewater treatment plant loads that I put into his model to conduct that test.

Q. Your Honor -- I'm sorry. Doctor, are these plots linear or log scale?

A. No, it should be noted that they're log scale. The loads that I put in are much, much larger than the loads Dr. Engel put in. That is apparent from looking at these plots.

Q. With respect to the bottom panel, can you describe the magnitude of the increases you applied to the nonpoint source loads in this test?

A. Yes. The convention is the same. The green, for reference, represents Dr. Engel's observed phosphorus loads at the bottom of the watershed. The red in this case on the bottom panel represents the nonpoint source loads from Dr. Engel's GLEAMS model, by the way, that he put into his routing model. And, again, the blue bars represent the nonpoint source loads that I put into his model.

Q. Doctor, after these loads were increased and the model was reran, did you compare the results to the results of Dr. Engel?
A. Yes. I did the same thing here. I -- with my loads, I attempted to recalibrate Dr. Engel's routing model.
Q. And how did those loads compare?
A. The -- the wastewater treatment plant load was -- the load that I put in was, I think, 345 times the load that Dr. Engel put into the model. The nonpoint source load was 15 times higher than his nonpoint source load.
Q. And how did the results of that test compare, observed versus predicted, with Dr. Engel's?
A. I was able to recalibrate Dr. Engel's routing model for both of these cases, and achieved R^2 values that were equal to or better than his.
Q. Doctor, what, if any, conclusions did you draw from this test?
A. Well, I guess, simply put, Dr. Engel's routing model can't tell the difference between the loads he put into the model and the wildly unrealistic loads that I put into the model.
Q. Let's talk about -- I think you referred to it as the S&P 500 test?

A. Yes.
Q. What was the purpose of that analysis?
A. Well, after seeing results from these first three tests, it became apparent to us that we could put in numbers over extremely wide ranges, and the model could still be calibrated to the observed data.
So I guess we decided to see how far we could push it, and we said -- I just -- I took made-up numbers that had nothing to do with phosphorus loads, we put them into the model, and that was the S&P 500 test.
Q. Doctor, when you did that, were you able to produce loads that matched the observed loads of the downstream?
A. Yes. Again, I was able to recalibrate that model and achieve calibrated -- results as good as Dr. Engel's original model.
Q. Doctor, did you provide in your expert report a chart setting out the results of this analysis?
A. Yes, I did.
Q. Could you turn in your binder to -- I believe it's tab 4, and find Defendants' Joint Exhibit 2416.
A. Yes.

Q. For the record, could you identify Defendants' Joint Exhibit 2416.
A. That's Figure 21 from my expert report.
Q. Doctor, did you prepare Defendants' Exhibit 2416?
A. Yes, I did.
Q. Can you identify the source of the information or data that is shown in this exhibit?
A. I ran this test only for the Illinois River subwatershed, which is the largest of the three. The top panel actually contains the same results. They contained Dr. Engel's results for his calibration and purported validation for his routing model. That's from his expert report. The bottom panel contains the results from the S&P test I conducted.
MR. GEORGE: Your Honor, at this time, we'd offer into evidence Defendants' Joint Exhibit 2416.
THE COURT: Any objection?
MR. PAGE: No objection.
THE COURT: Defendants' 2416 is admitted.
Q. (By Mr. George) Doctor, what conclusions, if any, did you draw from this analysis?
A. I guess the simplest way to state it is, Dr. Engel's routing model can't tell the difference

between phosphorus loads that are realistic and numbers that are completely made up.

Q. What is it, Doctor, about Dr. Engel's routing model that allows it to consistently produce similar results, despite changes in the inputs?

MR. PAGE: Objection, Your Honor. This witness said he recalibrated the model. It's not the same model. That question is misleading.

MR. GEORGE: Your Honor, I think that's material for cross-examination, if he wants to explore it.

THE COURT: Overruled.

Q. (By Mr. George) Can you answer the question, please?

A. Please repeat the question.

Q. Sure. What is it about Dr. Engel's routing model that allows it to consistently produce similar results, regardless of the changes in the inputs?

A. Well, there are two things. It's an empirical, statistical equation. It does not explicitly represent any of the physical, chemical and biological processes that actually influence the transport, fate, delivery, the journey, the pathway of phosphorus through the Illinois River stream and network. In a sense, it's a free-spinning wheel.

Another reason is that in each case when Dr. Engel conducted his calibration and purported validation, he compared what he called his predicted loads to observed loads. I need to take a step back and set a foundation again.

The phrase "observed loads" is widely used, but it's -- strictly speaking, that's a misnomer. One doesn't observe loads. One observes flow, and one observes concentration. And when you multiply the two together, you get load.

So the X axis on all these plots we've looked at are Dr. Engel's observed loads at the outlet station at the bottom of the watershed, and they were computed by multiplying USGS flow times concentration.

What Dr. Engel did is his predicted loads on the vertical axis were not independently determined, because he also used the measured USGS flows at the bottom of the watershed to determine the predicted loads on the Y axis. So we have measured flow on the Y, measured flow on the X. And flow is a dominant influence on loads to Lake Tenkiller. So if you've got the same -- if you've got flow on the vertical and flow on the horizontal, then, in a sense, when you do these regressions,

you're almost regressing flow on itself, and you're almost guaranteed to get good results.

Q. Doctor, as a scientist with 36 years of experience with models, what do these tests that we've been discussing tell you about the integrity and reliability of Dr. Engel's models?

A. Well, in my opinion, the results from Dr. Engel's models are not scientifically defensible, they're not valid, and they're simply not reliable.

Q. Doctor, does that opinion you just expressed apply to both the GLEAMS application and the routing model?

A. Yes, it does, for reasons I set forth in my report.

Q. Did the corrections that Dr. Engel made to his work between his original report and his errata report confirm your opinion in any way?

A. Well, they actually did, because all the tests that we've been speaking about that I conducted were the basis for my own opinions, but Dr. Engel's errata represents the product of his own work. And he independently confirmed that his models give the same answer whether he includes the entire watershed or leaves half of it out. And that's completely

independent of anything I did.
Q. Dr. Engel testified on direct in this case that he omitted, I think, 23 hydrologic response units in the model runs to support his original report. You've reviewed that testimony, haven't you?
A. Yes, I did.
Q. As part of your work in this case, did you evaluate the size of each of Dr. Engel's HRUs?
A. Yes, I did.
Q. And what percentage of the total land area in the watershed did Dr. Engel omit from his original report?
A. Fifty-four percent.
Q. Now, Dr. Engel explained in his testimony from that stand how it was that his model could omit half the watershed and still generate the same answer. Have you reviewed that testimony?
A. Yes, I have.
Q. And I've reviewed it as well. Can you help us by explaining your understanding of what Dr. Engel is describing as the explanation for that.
A. Yes. The code was originally set up with a do loop index to go from one to nine to capture all the HRUs. It was set up first on Caney Creek. There are -- in Dr. Engel's GLEAMS model, there were 21

HRUs in the Illinois River subshed, 20 in Barren Fork, and 9 in Caney. Code was developed for Caney, copied over into the other folders. The do loop index wasn't changed. It remained at 9, so it captured all 9 in Caney, and only the first 9 of 20, 21 in Illinois, and the first 9 of 20 in Barren, so it left out 23.

So to answer your question, how could it give the same answer, well, the -- Dr. Engel had a calibration algorithm called the shuffled complex evolution algorithm. I'll call it SCE for short.

The SCE algorithm was given a model calibration target, and the model calibration target was where the loads -- Dr. Engel's observed loads to Lake Tenkiller at the bottom of the watershed.

And what the SEC algorithm did, it iterated through the GLEAMS model, it ran it over and over again, and it changed the values of seven model input parameters so as to ensure that the output of the GLEAMS model matched that target.

Q. Doctor, is that an appropriate adjustment, in your view?

A. Well, not -- well, not in this case, because what the parameter that that algorithm adjusted, the way it worked is that it adjusted primarily the rate

of application of animal waste phosphorus.

And basically what it did in this case, to give the same answer, is the algorithm added more load, it added all the load it needed to the parts of the watershed that Dr. Engel did include to compensate for the half that he left out. And that just simply is not scientifically defensible nor does it represent the reality of how animal waste is actually applied in the Illinois River Watershed.

Q. Doctor, you've mentioned a time or two calibration targets. What were the calibration targets for Dr. Engel's models?

A. The calibration targets were his observed phosphorus loads at the bottom of the watershed at the three outlet stations, and he used these targets for both his GLEAMS model and his routing model.

Q. Could you turn in your binder to tab 5 and find Tyson Demonstrative 248.

A. Yes, I'm there.

Q. Doctor, did you prepare this demonstrative exhibit?

A. Yes, I did.

Q. And can you describe generally what this exhibit is.

A. Yes. Let's work backwards from the locations

of the three USGS gauges at the bottom of the watershed. The watershed area above each -- there are three gauges, three subwatersheds, one above each of these gauges, and one is the Illinois, one is Barren Fork, and one is Caney Creek. What the graphic shows, it actually shows the stream and river networks within each of these subwatersheds.

Q. Doctor, using this demonstrative, can you explain the problems, in your view, with Dr. Engel's calibration approach?

A. Well, the calibration approach -- and I'm speaking specifically with GLEAMS here. The calibration targets that Dr. Engel used for his GLEAMS model simply do not correspond to what the GLEAMS model actually computed. That's the problem.

The GLEAMS model actually computes runoff of nonpoint source phosphorus to edges of fields. And those represent locations that are spatially distributed throughout the entire watershed. Some of them intersect these tributaries, some don't.

However, the calibration target that Dr. Engel used was the loadings to Lake Tenkiller. As I said, one, that's apples and oranges; that's not what GLEAMS is computing.

Number two, the locations at which GLEAMS is computing these loads to edges of field are spatially distributed throughout the watershed, and they are located in some cases up to a hundred miles away from the points in space where his calibration targets were computed. So that makes no sense.

Q. Is this calibration approach scientifically defensible, in your view?

A. Not in my opinion, no.

MR. GEORGE: Your Honor, this is sort of a transition point, if we'd like to take our midmorning break. It would be convenient for me, but I'd defer to you, obviously.

THE COURT: It would be convenient. And back here in the gallery, we have Mr. John Boozer, who's a student at the University of Oklahoma. Welcome. And, gentlemen, feel free to introduce yourselves to Mr. Boozer. If he has any questions, please make yourself available.

MR. GEORGE: Thank you, Your Honor.

THE COURT: We'll be in recess.

(Whereupon a recess was had.)

THE COURT: You may proceed.

MR. GEORGE: Thank you, Your Honor.

Q. (By Mr. George) Dr. Bierman, I want to go back

for just a moment to Demonstrative 248, which is a map of the watershed. And I want to ask you, if you could, to get out of your chair and go to the screen. And I want to go back through and have you explain again because, frankly, I got a little lost, and maybe some others did, too, the issue with the spatial distribution of edge-of-field locations in reference to these algal stations. Okay? Could you do that, please.

A. So the context is the calibration of Dr. Engel's GLEAMS and routing models?

Q. Yes, sir.

A. Okay. First, what Dr. Engel's GLEAMS model actually computes are nonpoint source phosphorus loads to edges of fields. And those locations are distributed throughout the entire watershed. Some of them abut these tributaries, and some of them don't. But they're spatially distributed throughout the Illinois River, Barren Fork and Caney creek. So that's the first point.

The calibration targets -- this is an important point. The calibration targets that Dr. Engel used for both of his models are the same, the -- his observed phosphorus loads to Lake Tenkiller at the three outlet stations at the

bottoms of the watersheds.

So for the GLEAMS model, even though it computed runoff and nonpoint source phosphorus loads at the edges of fields that were spatially distributed throughout the entire watershed, he calibrated them by comparing them to loads at the very bottom. That's not what GLEAMS computed, number one. And number two, those locations are up to a hundred miles away from the locations where the GLEAMS model was actually computing its results.

So in my opinion, that's not a credible approach.

The -- should I proceed --

Q. One more question, Doctor. Did he have available data that is more close in proximity to some of these locations?

A. Well, yes. The plaintiffs collected almost 150 edge-of-field samples, and Dr. Engel did not use those samples to compare with the results of his GLEAMS model.

Q. Thank you. Could you retake the chair, please.

A. You asked me about the routing model?

Q. I'm sorry. Doctor, please explain the issue with respect to the routing model.

A. The routing model -- the inputs to the routing model are the nonpoint source phosphorus loadings from Dr. Engel's GLEAMS model plus wastewater treatment plant loadings that he determined separately, all outside the model.

He puts those into the routing model. And again, the calibration targets are the three -- are his observed phosphorus loads at the bottom of the watershed.

So the routing model makes the connection between the loads he computed at the edges of fields, again, distributed throughout the watershed, and these three stations at the base of the watershed.

And the issue there is that he ignores everything that happens in between the edges of those fields and these three stations. He does not explicitly represent any of the transport, fate or delivery processes in over 3,000 miles of the watershed.

And, furthermore, those weren't the only data available to him, because distributed throughout the watershed in the stream and river network, there are almost -- there are about 250 sampling stations, and there are over 3,000

measurements of total phosphorus available that he could have used and, in my opinion, should have used to calibrate the routing model, but he ignored them all and leap-frogged the whole system and went right down to the three stations at the base of the watershed.

Q. Thank you, Doctor. Let's turn now to Dr. Wells' work. You reviewed Dr. Wells' work as well; is that right?

A. Yes, I did.

Q. Dr. Wells testified on direct examination that his model runs on phosphorus loads at the three USGS stations. Did you review that testimony?

A. Yes. The end point for Dr. Engel's model is basically the starting point for Dr. Wells' model.

Q. What is the source of the phosphorus loading inputs that feed into Dr. Wells' lake model?

A. The loadings that Dr. Wells used to calibrate his model for Lake Tenkiller were provided by Dr. Engel.

Q. Did some of those loadings come from the output of Dr. Engel's model?

A. None of the loads that Dr. Engel provided to Dr. Wells for calibration of his model came from Dr. Engel's model.

Q. What about the loads that were used for some of the prediction scenarios?
A. All of the loads that Dr. Wells used for all of his prediction scenarios, as well as his long-term hindcast scenario, they were predictions and hindcasts from Dr. Engel's model.
Q. In your opinion, are Dr. Wells' modeling predictions from his lake model adversely affected by the phosphorus load predictions from Dr. Engel?
A. Yes. All of Dr. -- the input loadings that Dr. Wells used for all of his predictions are flawed and unreliable and, hence, all of Dr. Wells' calculations with his lake model for water quality in the lake are flawed and unreliable.
Q. Doctor, did you evaluate the CE-QUAL-W2 model?
A. Yes, I did.
Q. In particular, did you evaluate the application of Dr. Wells of that model to Lake Tenkiller?
A. Yes, I did.
Q. Prior to your work in this case had you had any experience with CE-QUAL-W2?
A. Prior to this case, I personally never operated CE-QUAL-W2. This goes back to a statement I made previously. I've not used that modeling tool. In fact, for my work in Chesapeake Bay, the Potomac, I

used CE-QUAL-ICM, which is a far more sophisticated version of CE-QUAL-W2.

And the second point is that the science underlying CE-QUAL-ICM and the science underlying every water quality and watershed model I've ever done is the same science that's in CE-QUAL-W2.

Q. Did Dr. Wells use the official released version of CE-QUAL-W2 for his evaluations in this case?

A. No, he did not.

Q. What type of model did he use?

A. Well, he used what's called a beta version.

Q. What is a beta version of a model?

A. A beta version is a version that has passed preliminary testing and then it's released to a limited number of users for further usability testing. It provides the opportunity for any bugs to be discovered and reported back to the developers and then fixed.

Q. What is your understanding of the differences or changes between this beta version used by Dr. Wells and the official release version at that time?

A. There was a pretty long list of enhancements and bugs in the transition from the official released version to the beta version, but the

enhancement that's most relevant to Dr. Wells' use of the model in this case is that the beta version was given the capability to exploit computers with dual processors, and it allowed it to run much faster.
Q. Do you know whether Dr. Wells ran his beta version of the model for this case on a dual processor?
A. Yes. He told us that that's what he did.
Q. Doctor, have you ever heard of the concept of code verification as it relates to computer-driven environmental models?
A. Yes, I have.
Q. Could you explain what that is.
A. Well, code verification, it involves focusing on the computer code, the numerical solution method and ensuring that the computer code solves the equations correctly and provides the correct mathematical answers.
Q. Did you run any tests on the beta version lake model used by Dr. Wells?
A. Yes, I did.
Q. And could you describe why you ran those tests and what type of tests they were?
A. Yes. We took a similar approach with Dr. Wells' model, and that is we reviewed his model

files. We had no problem running his model. We must have run his model -- several hundred times, we ran his model. But in seeking to reproduce the results in his expert report, we simply couldn't do it. We got close, but we couldn't get there.

And Dr. Wells had given us -- his files were well documented, well organized. He gave us very specific instructions about what files he used, how he put them together. And we followed his instructions exactly. We still couldn't get there. So we took one step back and said basically let's verify the code.

Q. And have you heard of the term called "replication test"?

A. Well, yes. Basically that's what we did. Out of frustration, actually, that we couldn't reproduce the results, we backed up and said, let's see if we can take this model, same input file, same model, run it once on the computer and then run it again, same thing, and see if we get the same answer twice in a row.

And, in fact, we tried that. And to our surprise, we got different results the second time.

Q. How significant were the differences between the consecutive model runs and your replication

tests?
A. Well, it depends on what parameter one looks at, and it depends on what point in time and what's space on the lake. So it depends.
For example, we looked -- we did a detailed analysis of temperature. On average, the run-to-run differences with the same model were on the order of one to two percent. Some were higher; some were lower. In absolute terms, .1, .2 degrees centigrade.
Q. Are percent changes in those ranges significant in terms of the reliability or validity of Dr. Wells' model?
A. Well, again, it depends. Depends on context. For the calibration, those differences would be less significant. For example, if the lake is at -- if lake water is at 20 degrees centigrade, which is about 68 degrees, then a tenth, two-tenths of a degree absolute difference is only about a percent, so that's not -- probably would not affect the calibration very much.
But if one is using that calibration to compare two different scenarios in which temperature is important -- and it was in this case because the fish habitat volumes that Dr. Welch worked with

depended on both temperature and dissolved oxygen. If the difference between two scenarios is, say, two degrees centigrade, then a discrepancy of .2 degrees is, of course, much more significant.

But I think that really the overarching issue to me is that the scientific community would simply not accept the results from any model if the model couldn't -- if the results were not capable of being replicated. That's just not consistent with the scientific method.

Q. Doctor, are you the only one who has discovered this replication problem?

A. No, we're not.

Q. Who else?

A. This problem occurred --

MR. PAGE: Objection, Your Honor, hearsay.

THE COURT: Sustained.

Q. (By Mr. George) Do you have any personal knowledge of this issue being discovered independently by other scientists?

MR. PAGE: I think that still calls for hearsay.

MR. GEORGE: Let me back up and lay a foundation.

THE COURT: Thank you.

Q. (By Mr. George) Doctor, have you been involved in a TMDL that EPA is conducting in the state of Washington?
A. It's the Spokane River.
Q. You've been involved in that?
A. My company is involved, Dr. David Dilks is involved, and he's one of the four core members of my project team in this case.
Q. Do you know whether or not this issue of replication has been one of the issues that has come up in the context of that Spokane River EPA TMDL?
MR. PAGE: Your Honor, it still calls for hearsay. I have no ability to cross-examine Dr. David Dilks. He's going to repeat what he heard from Dr. Dilks.
THE COURT: I think that's correct. Sustained.
Q. (By Mr. George) All right. Dr. Bierman, do you know whether or not Dr. Wells has released a correction on his website related to CE-QUAL-W2?
A. Yes. There are updated release notes that appear on the Portland State University website pertaining to this version of the model.
Q. And do those updates attempt to address the replication issue?

A. There's an update that appears to relate to the replication issue, because the whole purpose -- one purpose of developing the beta version was to give the model the capability to utilize dual processors.

This update now allows the user the option of simply backstepping and selecting only a single processor. That doesn't seem to make sense on its face, because if the purpose of the enhancement was to make it run faster, you put out an update that allows you now to run it slower.

Q. Let's move away --

MR. PAGE: Your Honor, I move to strike that answer. I think it was speculation on his part. He didn't link up how the dual processor option had any relationship to a replication issue that he has testified to.

THE COURT: When you -- let me get a clarification here.

The question here on real-time was, Do those updates attempt to address the -- says "representation issue," but "replication issue," right?

MR. GEORGE: Correct, Your Honor.

THE COURT: And the answer didn't appear to

address replication but, rather, the fact that it didn't make sense because you could take a back step to use a single processor, and it doesn't make sense to use an update to run it slower. I think the objection is proper. Sustained. Go ahead.

MR. GEORGE: Let me rephrase, Your Honor.

Q. (By Mr. George) Dr. Bierman, what's your understanding of the issues that were addressed by the update to the CE-QUAL-W2?

A. My understanding of the update is that it pertained to the issue of the dual processor versus single processor. And if I could add that we not only determined there was a replication problem, we actually dove deeper. We ran the -- as we discovered by accident, we ran the model on dual-processor machines --

MR. PAGE: Your Honor --

THE COURT: Go ahead.

MR. PAGE: -- I object. It's not responsive to the question asked.

THE COURT: I'm not sure it's not. Overruled. Go ahead.

THE WITNESS: We drilled deeper. We have a large number of modeling computers at LimnoTech, most of them are dual-core processors. Some of them

are single core. We ran some of these tests on single-core processors and discovered that if we ran it twice -- if we ran it multiple times on a single processor machine, it did, in fact, replicate. If we ran it multiple times on dual-core processor machines, it did not replicate. And those files are in my produced materials.

Q. (By Mr. George) Thank you, Doctor. Let's move away from the inner workings of these models for a moment and talk about input data and assumptions.

Did you review Dr. Engel's testimony in this case that once phosphorus begins to move off of a field, it will necessarily continue in motion and reach the reservoir at the bottom of a watershed?

A. Yes, I did.

Q. Do you agree with that assumption?

MR. PAGE: Objection, Your Honor, this is not part of his expert report. This is new analysis.

MR. GEORGE: I'm asking the witness to comment on something that Dr. Engel said from the stand.

THE COURT: Overruled.

Q. (By Mr. George) Doctor, do you agree with that assumption?

A. Please state the question again.
Q. Sure. You reviewed Dr. Engel's testimony that once phosphorus begins to move off of a field, it will necessarily continue in motion and reach the reservoir at the bottom of a watershed. You reviewed that testimony?
A. Yes, I did.
Q. Do you agree with that assumption or statement?
A. No, I don't.
Q. Why not?
A. Well, I'll answer it in three parts. If there's a molecule of phosphorus in the middle of a field, and it begins moving toward the edge of field, it's not correct to assume that it will necessarily and inevitably make it there.

One reason is that there are many physical, chemical and biological processes that can impact the transport and fate of the journey. Another reason is that there might not be a pathway for it to make it there.

Another reason could be that as it gets near the edge of field, it might see a buffer strip and be unable to penetrate.

I should point out that buffer strips aren't the only best management practice. There's a

whole universe of Best Management Practices out there that have been developed by federal and state agencies to be put in place on land simply for the specific purpose of preventing that from happening.

The second part of my answer is -- let's jump head, let's suppose it makes it to the edge of field. It may or may not enter a stream and river network. For one reason, the edge of field may or may not intersect a stream. It might intersect a puddle, a lake, a ditch, a pond. It might intersect a road.

Finally, let's take the third step. If it does enter -- manage to enter the stream and river network -- and in this case, it would have to travel a hundred or so miles to make it to Lake Tenkiller -- again, there are many physical, chemical and biological processes that influence the fate, pathway and delivery, and impact the journey.

Q. Doctor, does Dr. Engel's routing equation actually model any of the fate and transport processes that you just described?

A. It does not explicitly model any of them.

Q. Are there computer models out there that actually account for and represent the fate and transport processes affecting a substance such as

phosphorus as it moves through a stream system?
A. Yes, there are.
Q. Could you provide the court with just a couple of examples of those.
A. AQUATOX, WASP, the stream and river network component of the HSPF model, just to name three.
Q. Doctor, have you ever heard the phrase "garbage in, garbage out" applied to computer-driven environmental models?
A. Yes, I have. I think I use that occasionally myself.
Q. What does that term -- what does that phrase mean in terms of input data?
A. Well, take a step back. Models synthesize data. Models are not a substitute for data. Given that, if you put flawed and unreliable data into the model, you're going to get flawed and unreliable results out.
Q. Doctor, you saw in my cross-examination of Dr. Engel that I covered a lot of the assumptions he made about litter applications. And I don't want to drill into necessarily that area and repeat that with you. But let's talk about the input data that Dr. Engel used for land cover or land uses in the watershed.

A. Yes.
Q. What dataset did Dr. Engel use for land cover or land uses in the watershed?
A. He began with the National Land Cover Dataset, NLCD.
Q. Who maintains that dataset?
A. My understanding is it's the USDA.
Q. What generally does that dataset show?
A. Well, it's remotely sensed imagery, and it shows land, and it comes with a number of codes that represent different operational categories of land cover.
Q. If a modeler is using the National Land Cover Dataset, does the modeler have to make some interpretations of those codes?
A. Yes. The codes don't correspond directly to urban land, pastureland, forest, cropland. The user needs to determine first what are the characteristics of the site of the watershed for the particular site-specific application and then make judgments about how to use those codes to classify areas for the particular watershed model.
Q. Now, is the land cover -- I'm sorry, the National Land Cover Dataset a dataset that's commonly used in the watershed modeling community?

A. Yes.

Q. Have you reviewed Dr. Engel's land use classification inputs into his model to determine whether his judgments are accurate and realistic representations of the actual land uses?

A. Yes.

Q. How did you conduct that review or investigation?

A. Well, we -- I overlaid aerial infrared imagery, looked at overlays of imagery --

MR. PAGE: Your Honor, I'm going to object. This witness testified in his deposition that he actually did not do this work and that he actually has never done this work before. I think it's a lack of foundation and it's hearsay.

THE COURT: Response?

MR. GEORGE: Your Honor, Dr. Bierman has testified that -- first of all, that's material for cross-examination. But, secondly, Dr. Bierman has testified that he worked with a staff and he reviewed all of their work product, and the opinions and testimony he's providing today are his own.

THE COURT: Overruled.

Q. (By Mr. George) Doctor, could you continue describing how you conducted that investigation.

A. Yes. Aerial infrared imagery was overlaid with portions of Dr. Engel's land use classifications, and we noted a number of discrepancies in his classification of pastureland.
Q. Doctor, did you include any of those overlay figures in your report?
A. Yes, I did.
Q. Could you turn to -- let's talk about them in a group first -- tab 6, 7 and 8 in your binder, which for the record are Defendants' Joint Exhibits 2398, 2399, and 2400.
Could you identify those exhibits for the record, please.
A. Yes. Those are all figures from my expert report.
Q. And could you describe generally, without getting into the details of a specific exhibit, the source of the information that is shown in those exhibits.
A. Yes. They're overlays of Dr. Engel's classifications in his model, GLEAMS model input files that he derived from the NLCD data overlaid with aerial infrared imagery, and we attempted to check Dr. Engel's classifications to determine if they were accurate and correct.

Q. Doctor, are these three exhibits the product of the investigation and review that you just testified about?
A. We found many discrepancies. These are simply illustrative results.
MR. GEORGE: I move for the introduction of Defendants' Joint Exhibits 2398, 2399 and 2400.
THE COURT: Any objection?
MR. PAGE: Yes, Your Honor. The objection is on the same basis that I objected to his testimony. This witness did not do this work nor does he have experience in doing this type of aerial photo interpretation.
THE COURT: Overruled. Exhibits 2398, 2399, and 2400 are admitted.
Q. (By Mr. George) Now, Doctor, let's start with Exhibit 2398 which is behind tab No. 6.
A. Yes.
Q. Can you describe what is shown in Defendants' Exhibit 2398?
A. Yes. This is an example of how land which was actually forested land was classified by Dr. Engel as pasture in his GLEAMS model input files.
Q. And with reference to the images, could you point out some examples of that misclassification?

A. Yes. Let's look at the bottommost panel. And we have a legend there that says, "Engel classified forest as forest," and the arrows point to those dark red portions. The aerial infrared imagery reveals that, in fact, they are forest; and, in fact, Dr. Engel classified that area as forest.

However, if we move over, the arrow that says, "Engel classified forest as pasture," that's the same type of land. The aerial infrared imagery saw forest. The shaded overlay indicates that Dr. Engel classified that as pasture.

Q. Turn to Defendants' Exhibit 2399, which is behind tab No. 7. And could you describe what is shown in that exhibit.

A. This is the same type of format, except here it depicts examples of urban land that Dr. Engel classified as pasture.

Q. Finally, could we turn to Defendants' Exhibit 2400, which is behind tab No. 8.

A. Yes.

Q. And, Doctor, could you describe what is shown in this exhibit.

A. Again, the format is the same as the three previous pictures, but here this illustrates that what the infrared imagery saw as roads were actually

classified as pastureland in Dr. Engel's GLEAMS input files.

Q. Are the areas shown in the last three exhibits that we just discussed the only instances of miscalculation that you found in your investigation?

A. No. There were many other instances. We prepared these as simply illustrative examples.

Q. What is the impact, if any, of these misclassifications of lands as pastures on the reliability of Dr. Engel's modeling work?

A. Well, in watershed models, if you don't get the land use types right, you can't get the nonpoint source runoff right. And the reason is that if a rainfall event occurs and if runoff occurs, the amount of runoff one gets, the amount of phosphorus per unit area one gets really depends on the type of land cover that the precipitation hits. So if you want to get the loads right, you need to get the land right.

Now, with respect to pasture, Dr. Engel classified more land as pasture in his model than actually exists in the real world in the Illinois River Watershed.

So one consequence would be that his model would overestimate the nonpoint source load from

pasture. As another consequence --

MR. PAGE: Objection, Your Honor, this is speculation. The witness hasn't provided any foundation to support his opinion.

THE COURT: Overruled.

Q. (By Mr. George) Please continue, Doctor.

A. Another consequence is that inside Dr. Engel's model, animal waste phosphorus is being applied to a larger pasture area than it actually is applied in the real world in the Illinois River Watershed.

Q. Let's move to urban areas. Doctor, did you review the input values and assumptions that Dr. Engel used in his model to simulate runoff of phosphorus from lands that he classified as urban?

A. Yes, I did.

Q. Does GLEAMS have default values or coefficients designed to represent the physical processes that exist in urban areas?

A. No, because GLEAMS is an Ag model. It is not designed to represent urban areas.

Q. Based upon your review, did Dr. Engel model urban areas in a manner that's representative of urban areas?

A. He didn't accurately represent the characteristics of urban areas, in my opinion.

Q. Can you explain the basis for that statement?

A. Yes. The GLEAMS watershed model, for each land use type -- and urban land use is one of the land use types used by Dr. Engel -- the GLEAMS model requires that nutrient inputs be specified and that hydrology inputs be specified. Let's talk about the nutrient inputs first.

The nutrient parameter input file that Dr. Engel input to his GLEAMS model for urban land represented a crop type, ICROP=2, if anyone is taking notes on that specifically. That corresponds to alfalfa hay and it's based on an example from the GLEAMS manual.

Let's turn to hydrology. The GLEAMS model requires that the user specify a curve number. Simply put, the curve number determines, if a precipitation event occurs, how much runoff occurs per unit area from the land surface, and that's what the curve numbers do. So the user needs to specify that.

Now, I investigated Dr. Engel's hydrology input files. The initial value he specified for the curve number for his hydrology file for urban land use was, in my opinion, reasonably representative of the impervious surfaces that exist in urban land

use.

However, the calibration process that Dr. Engel used varied a number of the model input parameters so as to achieve correspondence with the calibration targets.

For the hydrology calibration, one of the input parameters that was varied was the curve number. So after the calibration was completed, the curve number in Dr. Engel's calibrated model was very different than the initial curve number he specified. It was much lower. The initial values, I believe, were 85 to 89. He ended up at values below 50.

And in the GLEAMS manual, it's very clear that curve numbers that low correspond to the runoff characteristics of wooded areas.

Q. Are wooded areas, based upon your professional experience, an appropriate surrogate for urban areas in terms of curve numbers?

A. No, they're not. And basically inside Dr. Engel's model, the hydrology characteristics that were actually operating in his calibrated model represented wooded areas and not urban areas.

Q. Doctor, the last input value used by Dr. Engel that I want to discuss with you is the phosphorus in

the soil profiles in the Illinois River Watershed. Did you investigate those input values?
A. Yes, we did.
Q. Does Dr. Engel's GLEAMS model of the watershed require specification of phosphorus concentrations in soils at various depths in the watershed?
A. Yes, it does. Dr. Engel --
Q. I'm sorry, let me ask a question. Did you analyze Dr. Engel's GLEAMS model files to determine the total amount of phosphorus in all depths in the IRW soils that was specified for his modeling work?
A. Yes.
Q. And can you explain how you conducted that analysis.
A. Yes. As I mentioned previously, Dr. Engel divided the Illinois River Watershed into 50 HRUs. Beneath each of these 50 HRUs, there were between three and five vertical layers in the soil, and the depths of these layers varied.
So basically the GLEAMS model is basically -- it's a grid of boxes that goes down that represents the soil and phosphorus.
I investigated his model files and determined the areas of the HRUs, the number of layers for each HRU, the depth of each layer from

which we could compute the volume of each box. And we investigated the amount of phosphorus, concentration in each of these boxes. And there's nothing difficult about this. It's just a tedious bookkeeping exercise where you just compute the mass in each box, and then at the end, you add up the mass in all the boxes.
Q. Did you, in fact, at the end sum up the total amount of phosphorus in the soils that Dr. Engel included in his model?
A. Yes, I did.
Q. How much phosphorus did he assume was in these soils in the watershed at all depths?
A. It was about 6.4 million tons.
Q. Can you explain what that 6.4 million tons represents.
A. That represents basically a snapshot in time corresponding to his calibrated GLEAMS model.
Q. Doctor, do you recall what annual value for poultry litter phosphorus, as Dr. Engel called it, he assumed in his GLEAMS model?
A. Yes. On page D-18 in Dr. Engel's expert report, he has a number of 4,642 tons of poultry P per year, and that was taken from Appendix B, the mass balance conducted by Meagan Smith. And that's

the number he puts forth as the phosphorus added each year due to poultry P.
Q. In your report, did you provide a comparison of the tons of phosphorus that Dr. Engel assumed was present in the soils in his model with this addition of 4,642 tons of phosphorus annually?
A. Yes, I did.
Q. Can you provide us with the results of this comparison?
A. The 4,642 tons of P that Dr. Engel assumed is added each year is approximately .07 percent of the total phosphorus that's already present in the soil in his GLEAMS model.
Q. You mentioned Meagan Smith's mass balance report. Did you review that report as well?
A. Yes, I did.
Q. Do you recall seeing her pie chart presenting the various different sources of phosphorus additions to the watershed that she identified?
A. Yes, I did.
Q. Let me ask you to turn to tab 9 and find Tyson Defendants' Demonstrative 230.
A. Yes, I have it.
Q. Did you prepare this demonstrative?
A. Yes.

Q. Can you explain what it demonstrates.
A. Well, to set a foundation, the mass balance conducted by Meagan Smith, the best way to think about it is it encased the entire Illinois River Watershed in a bubble -- air, land and water. And if phosphorus entered that bubble, it was considered a source. If phosphorus left that bubble, it was considered a sink, or a loss.
If we look at this pie chart here, the small slice which indicates the all watershed sources of 0.09 percent, that slice represents the amount of phosphorus that Meagan Smith assumed comes into that bubble in a year.
The large yellow slice, basically the whole pie, the 99.91 percent, represents the amount of phosphorus in the IRW soil in Dr. Engel's GLEAMS model.
Q. Now, Doctor, I want to switch subjects on you for a moment. You said earlier that Dr. Engel used what he called observed phosphorus loads at the three USGS stations nearest the lake to calibrate and validate his model; is that correct?
A. Yes.
Q. And can you explain where those observed loads come from and whether they're actually measured?

A. I think I mentioned previously the word "observed loads" is frequently used. But strictly speaking, loads are not observed. What's observed are concentrations, and what's observed are flows. And when one multiplies flow times concentration, one gets load.

I should also point out that the use of the phrase "observed loads" can be convenient because that's often used to distinguish between loads that are based on actual data versus loads that might come out of a model.

Q. Doctor, are you familiar with any regression approaches that are used to calculate observed loads from measured data?

A. Yes, I am.

Q. Is there a method or series of methods that are widely used in the modeling community?

A. Yes. The U.S. Geological Survey has developed a package of programs that's called LOADEST. That's L-O-A-D-E-S-T. And it's a package of statistical programs for tributary load estimation.

Q. Can you turn in your binder to tab 10 and find Oklahoma Exhibit 1237 which is already in evidence. Are you familiar with that document?

A. Yes, I am.

Q. What is it?
A. It's Table 5.3 from Dr. Engel's expert report, and it summarizes on an annual basis his observed phosphorus loads for each of the three subwatersheds he modeled, and then sums them up for a total load.
Q. Doctor, do the loads set forth on this exhibit, Table 5.3 from Dr. Engel's report, correspond to the phosphorus loads that Dr. Engel actually used to calibrate his model?
A. No, they don't.
Q. Did you check Dr. Engel's calculations of daily total phosphorus loads that he actually used in his modeling work?
A. Yes, I did. I should state that he used daily loads for the actual calibration process. These loads here in this exhibit are annual. But what I did is I added up the daily loads and computed annual loads and compared them to what was in Table 5.3, and they didn't match.
Q. Can you describe what you discovered when you reviewed the calculations by Dr. Engel to arrive at his observed phosphorus loads?
A. Yes. Dr. Engel stated that he used the USGS LOADEST program. And from review of his produced materials, I determined that he used LOADEST model

8. LOADEST has about 12 or 13 different models in it.

He also stated in his expert report that he used -- and it's indicated right here in the caption to Table 5.3 in this exhibit -- he used phosphorus data based on -- from the U.S. Geological Survey and from OWRB.

And I reviewed his -- again, reviewed his model input files, and I determined that he made a large number of errors in taking the OWRB measurements and organizing them and formatting them for input to the LOADEST program.

There were a large number of just flat-out mistakes, numbers were incorrect. There were a large number of OWRB data that were simply ignored.

Q. Did these errors that you discovered impact the loads that are set out on Table 5.3 and the loads that Dr. Engel actually used for his calibration?

A. Yes, they did.

Q. Did you recalculate the observed phosphorus loads without the data errors that you discovered?

A. Yes, I did.

Q. And did you compare those recalculated loads against Dr. Engel's loads?

A. Yes, I did.

Q. Did you include a chart in your report setting out the results of this analysis?
A. Yes, I did.
Q. Could you turn in your binder to tab 11 and find Defendants' Joint Exhibit 2413.
A. Yes.
Q. Could you identify for the record Defendants' Joint Exhibit 2413.
A. This is Figure 18 from my expert report.
Q. Did you prepare this exhibit?
A. Yes, I did.
Q. And can you describe generally the source of the information that's shown?
A. Yes. Again, we have results for each year from 1998 through 2006. And what this chart depicts are the differences between my corrected loads and Dr. Engel's incorrect loads.
And I compared my corrected loads to two different versions of Dr. Engel's loads. I -- the blue bars showed the comparison between my corrected loads and the loads in his Table 5.3 in his expert report.
The red bars are the differences between my corrected loads and the loads in what I've referred to as the p_model_10_15.xls on the legend, and that

is Dr. Engel's routing model, and that's the latest version of his routing model.

Q. Doctor, how substantial were the differences between the loads calculated by Dr. Engel and the loads recalculated by you, having corrected the data errors?

A. It depends on the year and it depends on which set of Dr. Engel's loads we're comparing. If we look at the blue bars, which are the results in his expert report, they range from a low -- they're about 23 percent low to about 15 percent high.

If we look at his -- the loads he used to calibrate his routing model, they range from about 25 percent low to about 10 percent high.

MR. GEORGE: Your Honor, I move for the introduction of Defendants' Joint Exhibit 2413.

THE COURT: Any objection?

MR. PAGE: No objection.

THE COURT: 2413 is admitted.

Q. (By Mr. George) Doctor, let's move to Dr. Wells' lake modeling again, if we could. It's been established through testimony in this case that Dr. Wells used the output of various forecasts from Dr. Engel's for some of his predictive scenarios. You're familiar with that, aren't you?

A. Yes.
Q. Did Dr. Wells use the output of Dr. Engel's model to calibrate his lake model?
A. No, he did not.
Q. What did he use?
A. One step back. Dr. Wells's model for Lake Tenkiller was calibrated to data for the period 2005, 2006 and the first nine months of 2007.
Dr. Engel's model computed loads for 2005 and 2006, but he did not use those computed loads when he determined the total phosphorus loads that he passed forward to Dr. Wells.
What Dr. Engel did was, again, he used LOADEST and he used observed flow and concentrations at the three outlet stations for those three years and computed loads based on data as opposed to his model output.
Q. Just so we're clear, the loads that Dr. Wells used were calculated by Dr. Engel; is that right?
A. The loads that Dr. Wells used for his calibration were calculated by Dr. Engel and they were based on observed data, not Dr. Engel's model output.
Q. Did Dr. Wells use any of the load calculations that we just discussed from the prior exhibit?

A. Yes. He used the same -- he used the same USGS method, but he applied it to the data in a different way than he applied it to develop his observed loads that he used to calibrate his own model.
Q. Did you check the phosphorus load estimates that Dr. Engel passed to Dr. Wells?
A. Yes, I did.
Q. And what did you find?
A. That they were incorrect.
Q. What types of mistakes or errors did you discover?
A. The total phosphorus loads, again, it was data errors, many data errors in translating the primary observed data as reported by the agency and getting that into the LOADEST input files that Dr. Engel used.
Q. Doctor, did you correct those phosphorus load estimates, the data errors in those estimates, and recalculate them and compare them to Dr. Engel's calculations?
A. Yes, I did.
Q. And did you include in your report a figure that shows the results of that comparison?
A. Yes, I did.
Q. Could you turn to tab 12 and find Defendants'

Joint Exhibit 2417. Can you, for the record, identify that exhibit.
A. Yes. This is Figure 22 in my expert report.
Q. Did you prepare this exhibit?
A. Yes, I did.
Q. And can you describe generally the source of the information that is shown.
A. Here we have results for only three years, because Dr. Wells ran his model for three years; more specifically, all of 2005 and '6 and the first nine months of 2007.
Again, these bars show the differences between my corrected loads and the loads that Dr. Engel computed to pass forward to Dr. Wells. These are for total phosphorus.
I've shown four bars for each year. The first three bars correspond to the individual results for the individual three subwatersheds. The fourth bar, the purple bar, corresponds to the total load to Lake Tenkiller.
Q. Doctor, how substantial was the impact of the errors made by Dr. Engel on the calculated loads?
A. It depends on year. And in this case, it depends on subwatershed. Those loads differ by -- they're about five percent low in Barren Fork in

2005, and they're about 50 percent too high in Caney Creek in 2007.

MR. GEORGE: Your Honor, I'd move for the introduction of Defendants' Joint Exhibit 2417.

THE COURT: Any objection?

MR. PAGE: No objection.

THE COURT: 2417 is admitted.

Q. (By Mr. George) Dr. Bierman, Dr. Wells testified that his model also uses a specific type of phosphorus known as soluble reactive phosphorus to simulate algae growth in the lake. You're familiar with that?

A. Yes.

Q. Where did Dr. Wells get his soluble reactive phosphorus loads?

A. Those loads were also computed by Dr. Engel.

Q. And did you review those computations?

A. Yes.

Q. Did you review the primary data from which Dr. Engel made those computations?

A. Yes, I did.

Q. What did you find as a result of that investigation?

A. The SRP loads that Dr. Engel computed were also incorrect.

Q. How were they incorrect?
A. Here, there was a new element. There were data errors, as there were in the two previous sets of loads that we discussed, but there was actually a more egregious error, because Dr. Engel used the wrong phosphorus data to conduct the load estimation. He used data for soluble phosphorus, not soluble reactive phosphorus. They're not the same thing.
Q. Does the USGS capture and report both types of data?
A. Yes, they do.
Q. How do you know that Dr. Engel used the data from USGS for total dissolved phosphorus as opposed to soluble reactive phosphorus?
A. I reviewed carefully Dr. Engel's produced materials for his LOADEST calculations. Those materials contained the primary data that he got from USGS, and the parameter codes and descriptions of what those codes were was very clear. One was soluble phosphorus, I believe that's -- I'll have to go from memory. I believe that's parameter code 00661. It's in my expert report. And the parameter code for soluble reactive phosphorus is different and the descriptor is different. I believe that

code is 00671.

Q. Dr. Bierman, does this present a problem, a reliability issue with respect to Dr. Wells' model?

A. Well, it does, because soluble phosphorus or total dissolved phosphorus -- those names can be interchangeable -- soluble phosphorus includes soluble reactive phosphorus, the form that algae require directly. But it also includes other forms of phosphorus, dissolved organic phosphorus, for example, that are not immediately available to algae.

So the use of soluble phosphorus in place of soluble reactive phosphorus inevitably will result in overestimation of the phosphorus loads that drive algal growth in the lake.

Q. Doctor, did you recalculate the loads using soluble reactive phosphorus as opposed to soluble phosphorus to determine the significance of the difference between those loads?

A. Yes, I did.

Q. Did you include in your report a figure that shows the comparison between the total dissolved phosphorus loads calculated by Dr. Engel and the actual soluble reactive phosphorus loads?

A. Yes, I did.

Q. And could you turn to tab 13 in your binder, please.
A. Yes.
Q. Could you identify this document for the record which is marked Defendants' Joint Exhibit 2418.
A. Yes. This is Figure 23 of my expert report.
Q. Did you prepare this exhibit?
A. Yes.
Q. Does this exhibit relate to the analysis that we just discussed?
A. Yes, it does.
Q. Can you identify the source of the information shown on this exhibit?
A. Yes. The format is identical to the previous graph. And this shows -- these bars represent the differences between my calculations of correct SRP loads from the watershed to Lake Tenkiller and the soluble phosphorus loads that Dr. Engel actually computed.
Q. And what is the significance or the magnitude of the difference between those two calculations, Doctor?
A. Well, again, it depends on subwatershed and depends on year. But first we should note that independent of watershed and independent of year,

all these loads are too high. None of them are too low. And this speaks to my point that soluble phosphorus contains other phosphorus forms besides soluble reactive phosphorus.

So in response to your question, if we -- these differences range from about a five percent overestimate in 2006 and 2007 for Illinois to almost 120 percent overestimate for Caney Creek in 2005.

Q. Doctor, what is the impact of this mistake on the reliability of Dr. Wells' lake model?

A. Dr. Wells' lake model quantifies the relationship between phosphorus loads that come into the lake and the amount of algae that are growing in the lake and water quality in the lake in terms of algae, dissolved oxygen and so forth.

If the model is calibrated -- if too much phosphorus load is put into the model, if too much SRP is put into the model, the calibration will be flawed because the model will try to grow too much algae, and the water quality will be computed incorrectly.

Basically what this means is that the load response relationship represented by Dr. Wells' lake model is incorrect. It's flawed.

MR. GEORGE: Your Honor, I'd offer into

evidence Defendants' Joint Exhibit 2418.

THE COURT: Any objection?

MR. PAGE: No objection.

THE COURT: 2418 is admitted.

Q. (By Mr. George) Doctor, I'm going to take a step back for a moment and ask you some general summary-type questions. Based upon your review of Dr. Engel's modeling work, do you have an opinion as to whether Dr. Engel's modeling results provide a realistic and reliable representation of phosphorus loading to Lake Tenkiller for either current, historical or future conditions?

A. Yes, I do.

Q. What is that opinion?

A. My opinion is that Dr. Engel's entire modeling framework is conceptually flawed. My opinion is that the methods that Dr. Engel used to apply that flawed conceptual framework to the IRW in this case are full of numerous errors and, likewise, are completely flawed.

My opinion also is that the results from Dr. Engel's model for his calibration and purported validation period and all of the results for any prediction scenarios he conducted, as well as his 100-year hindcast, are not scientifically

defensible, they're not valid, and they are unreliable.

Q. Doctor, based upon your review of the modeling work of Dr. Wells, do you have an opinion as to whether Dr. Wells' modeling results provide a realistic and reliable representation of water quality for the lake for either current, historical or future conditions?

A. Yes, I do.

Q. What is that opinion?

A. The water quality computed by Dr. Wells' model for his calibration period, those results are flawed due to the flawed and unreliable inputs for total phosphorus and soluble reactive phosphorus provided to Dr. Wells by Dr. Engel.

I'm also of the opinion that because -- let me restate. For all of Dr. Wells' forecast scenarios and predictions, as well as his 100-year hindcast, he used the flawed and unreliable outputs, predictions, from Dr. Engel's flawed models. Therefore, all of Dr. Wells' forecast results and hindcast results are similarly flawed and unreliable.

MR. GEORGE: Your Honor, this is a transition point for me, and we are at the noon

Hour, if this would be an appropriate time for our lunch break.

THE COURT: It would. Let's be in recess until 1:10.

(Whereupon a recess was had.)

REPORTER'S CERTIFICATE

I CERTIFY THAT THE FOREGOING IS A TRUE AND CORRECT TRANSCRIPT OF THE PROCEEDINGS IN THE ABOVE-ENTITLED MATTER.

S/Terri Beeler
Terri Beeler, RMR,FCRR
United States Court Reporter